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Mixing induces long-term hyperthermia in growing pigs

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Abstract

The purpose of this experiment was to determine whether body temperature is a sensitive parameter to measure long-term effects of stress in pigs. Mixing of unacquainted pigs is a severe stressor that has detrimental effects on health, production and welfare. We measured deep body temperature after mixing growing pigs. Five pigs of 15 weeks of age, each individually housed with a companion pig, were mixed with two unacquainted congeners. Deep body temperature, heart rate and activity were recorded by radiotelemetry 9 days prior to until 8 days after mixing. These parameters were also recorded in five control pigs (individually housed with a companion pig) during the same time span. Behaviour during the light period was recorded on videotape on the day of mixing and on three subsequent days. Mixing induced a significant rise in body temperature that lasted for 8 h after mixing. Although heart rate and general activity level did not significantly differ between mixed and control pigs, mixing significantly increased the frequency of fighting and reduced the frequency of eating. In conclusion, the present experiment shows that mixing induces a long-lasting hyperthermia in pigs. Thus, deep body temperature may be used as a sensitive parameter to measure long-term effects of stress in pigs.

Keywords: activity, body temperature, heart rate, pigs, stress.

Introduction

Measurements of body temperature are frequently used to determine psychological stress. The acute rise in body temperature in response to a stressor (stress-induced hyperthermia), lasting for 1 to 2 h, is a well described phenomenon in various species (e.g. in rodents: Kluger *et al.*, 1987; Zethof *et al.*, 1994; in humans: Brieze, 1995; in pigs: Parrott and Lloyd, 1995; de Jong *et al.*, 1998). However, stress may not only have an acute effect on body temperature, as more long-lasting effects of stress on body temperature have been reported (Tornatzky and Miczek, 1993; Meerlo *et al.*, 1996). When rats are defeated in a social confrontation, a sharp reduction in the amplitude of the body temperature rhythm lasting for 4 days was observed, which was due to an increased body temperature during the light period (Meerlo *et al.*, 1996). When rats were subjected to social defeat on 5 days consecutively, the circadian rhythm in body temperature was changed during and 5 days after the stress period (Tornatzky and Miczek, 1993).

Mixing of unacquainted pigs is a common phenomenon in pig husbandry that causes social

stress. Severe fighting may occur and previous studies showed that mixing of unacquainted pigs has detrimental effects on health, production and welfare (Rushen, 1987; Ekkel *et al.*, 1995; McGlone and Curtis, 1985; Ekkel *et al.*, 1996). In the short term, mixing of unacquainted pigs may lead to a high frequency of agonistic behaviour, increased occurrence of injuries (Ekkel *et al.*, 1995; McGlone and Curtis, 1985) and a decreased cellular immune reactivity (Ekkel *et al.*, 1995). In the long term, mixing of unacquainted pigs may lead to a decreased growth rate and an increased occurrence of health problems (Ekkel *et al.*, 1995 and 1996).

The present experiment investigated whether body temperature is a sensitive parameter to measure long-term effects of stress in growing pigs. Since body temperature is often used as an indicator of psychological stress (e.g. Kluger *et al.*, 1987; Zethof *et al.*, 1994; Brieze, 1995; Parrott and Lloyd, 1995), it is likely that a severe stressor such as mixing unacquainted pigs would have a large effect on deep body temperature. In addition, general activity and heart rate were measured in response to mixing. Changes in body temperature, heart rate and activity

were recorded by radiotelemetry. This allowed continuous monitoring of the parameters without disturbing the animals (de Jong *et al.*, 1998).

Material and methods

Animals and housing

Ten crossbred castrated boars (Great Yorkshire × (Great Yorkshire × Dutch Landrace)) were used in the experiment. Experimental animals were randomly selected at weaning (28 days of age) together with a companion pig from the same litter and each housed individually with their companion pig in pens (1.6 × 2.9 m) with half concrete slats and half concrete area covered with straw. All pens were in the same room and the environmental temperature was kept at 21°C. Artificial lights were on from 06:00 to 18:00 h and no daylight was visible. Food and water were available *ad libitum*. Each day, the pens were cleaned and fresh straw was supplied between 06:00 and 07:30 h and the pigs were checked by the caretaker between 14:00 and 15:00 h. At 9 weeks of age, experimental pigs were implanted with a transmitter measuring body temperature, heart rate and activity (see below).

Surgery

Biotelemetric transmitters (type TA10CTA-D70, DataSciences, St Paul, MN, USA) were implanted intraperitoneally in the experimental barrows at 9 weeks of age as previously described (de Jong *et al.*, 1998). Surgery was carried out under aseptic conditions. In short, pigs were sedated with azaperone intramuscularly (Stresnil® 1 cm³/kg, Janssen Pharmaceutica, Tilburg, The Netherlands) and subsequently anaesthetized with metomidate hydrochloride intravenously (Hypnodil® 2.5 cm³/5 kg, Janssen Pharmaceutica). The transmitter body was implanted in the peritoneal cavity. Electrode leads were positioned caudal and cranial to the thorax as described by de Jong *et al.* (1998). Pigs were treated with antibiotics (Ampicillin® 20%, AUV, Cuijck, The Netherlands). The experiment was started following a 5-week recovery period.

Telemetry system

Heart rate, body temperature and activity were measured by means of radiotelemetry. Frequency modulated heart rate and deep body temperature signals were received by four antennas hanging over the pen, that were connected to a multiplexer (RMX10, DataSciences) combining the signals of different antennas to one output. Signals of different pigs were routed via a matrix (BCM100, DataSciences) to a personal computer containing the LabPro Analysis software (version 3.1, DataSciences) for analysis of the data. General activity was

telemetrically monitored by measuring the movement of the pig with respect to the receivers.

Mixing procedure

At 15 to 16 weeks of age, half of the pigs (no. = 5, experimental group) were mixed with two unfamiliar castrated boars of the same age in their home pen. Two hours before mixing, all pigs were given a number painted on their back; at 11:40 h, two pigs were taken out of their pen, transported to the building housing the experimental animals (duration ± 5 min) and gently driven into their pen. Behaviour, body temperature, heart rate and activity were measured as described below.

Body temperature, heart rate and activity measurements

Body temperature, heart rate and activity were measured for 9 days at 14 weeks of age. Pigs were mixed at day 10, and variables were measured until 8 days after mixing. Body temperature and heart rate were recorded for 20 s every 5 min. Activity was observed continuously and noted at 5-min intervals. Control pigs were measured at the same time intervals as the mixed pigs.

Behavioural observations

Behaviour of the control and mixed pigs was recorded on videotape during the light period after mixing (11:45 to 18:00 h) and on 3 days subsequently after mixing during the light period (06:00 to 18:00 h). The posture and behaviour of each pig was scan sampled every 5 min according to the ethogram described in Table 1. Thus, for each posture and each behavioural element the frequency was observed and scored.

Table 1 Ethogram of the behavioural measurements

Definition	
Posture	
Lying	Lying on side or sternum
Standing	Standing, walking, running on four legs
Sitting	Standing on fore-legs, hind quarter on the floor
Behaviour	
Walking	Walking or running through the pen
Exploring pen	Rooting, sniffing, touching the pen
Exploring substrate	Rooting, sniffing, touching the substrate
Fighting	Biting, headknocking, pushing, lifting another pig or being bitten, headknocked, pushed or lifted by another pig in rapid succession
Eating	Time spent with the head in the feeder
Other	All other behaviour

Data reduction and statistical analysis

To study the long-term effects of mixing on body temperature, heart rate and activity, data were averaged over 2 h using the LabPro Analysis software (Version 3.1, DataSciences). Effects of mixing on 2-h averages of body temperature, heart rate and activity and frequency of behavioural elements were analysed with an analysis of variance model with treatment as a fixed effect. Components were estimated with a restricted maximum likelihood model (REML) procedure (Genstat 5 Committee, 1989). Residuals were checked and homogeneity of variance; homogeneity of variance was found for all data. Differences were considered significant if $P < 0.05$.

Results

Before mixing, body temperature, heart rate and general activity level did not differ significantly between the treatments. Mixing induced a significant rise in deep body temperature that lasted until 8 h after the moment of mixing (Figure 1) ($t = 2, 4, 6$ h after mixing: $P < 0.01$; $t = 8$ h after mixing: $P = 0.07$, tendency). Although mixed pigs also had a higher body temperature than control pigs from 10 to 18 h after mixing (Figure 1), differences in deep body temperature level between control and mixed pigs were not significant. Heart rate and activity level, as measured by the transmitter, did not significantly change in the mixed pigs as compared with the control pigs (Figure 1).

Detailed analysis of the behaviour revealed that the frequency of fighting was significantly ($P < 0.001$) higher in the mixed pigs than in the control pigs on the day of mixing (Figure 2). Frequency of eating was significantly ($P < 0.05$) lower in mixed pigs than in the control pigs on the day of mixing (Figure 2). Mixed pigs did not differ in other behaviours and in frequency of lying, sitting or standing from the control pigs on the day of mixing (Figure 2). On days 1, 2 and 3 after mixing, mixed and control pigs did not differ significantly in the frequency of the behavioural elements (data not shown).

Discussion

The principal finding of this experiment was that after mixing of unacquainted pigs the deep body temperature was significantly increased for 8 h. Mixed pigs had a higher frequency of fighting on the day of mixing and a lower frequency of eating. However, no effect of mixing on heart rate and general activity level was observed.

Mixing of unacquainted pigs is a severe stressor that has acute as well as long-term effects on behaviour

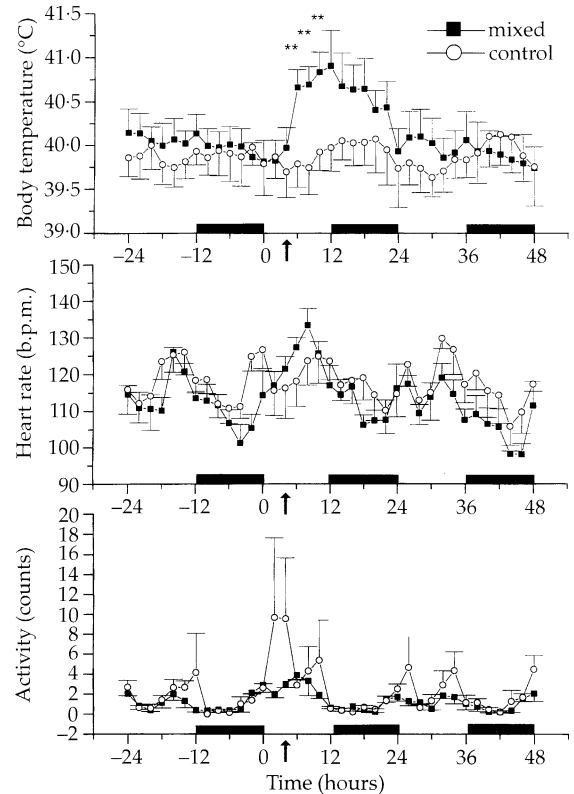


Figure 1 Effects of mixing on body temperature, heart rate (beats per min) and activity. Data represent the 2-h averages \pm s.e. of deep body temperature (upper panel), heart rate (middle panel) and general activity (lower panel) of mixed and control pigs. The moment of mixing is indicated by an arrow. Black bars represent the dark period. ** $P < 0.01$ mixed pigs *v.* control pigs.

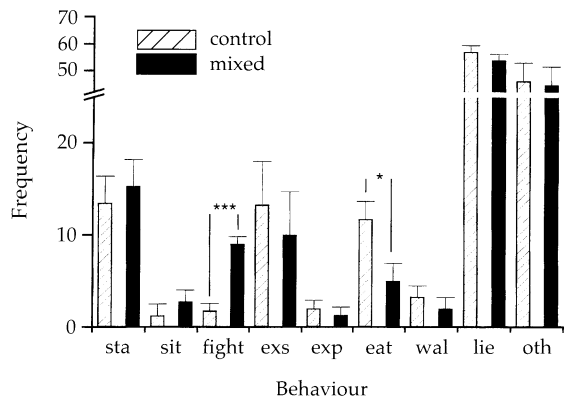


Figure 2 Frequency (mean \pm s.e.) of positions and behavioural elements for control and mixed pigs on day 1 during the light period after mixing: sta = standing; sit = sitting; fight = fighting; exs = exploring substrate; exp = exploring pen; eat = eating; wal = walking; lie = lying; oth = other behaviour. * $P < 0.05$, *** $P < 0.001$ mixed pigs *v.* control pigs.

and health (Parrott and Misson, 1989; Ekkel *et al.*, 1995 and 1996; McGlone and Curtis, 1985; Otten *et al.*, 1997). This experiment shows that a severe stressor like mixing induces a hyperthermia lasting for several hours. Observations of behaviour revealed that the frequency of fighting was only significantly increased on the day of mixing. This confirmed previous experiments showing that after mixing of unacquainted pigs, fighting is most apparent during the 1st h after mixing, declining thereafter and reaching very low levels after 3 h (Friend *et al.*, 1983; Rushen, 1987; Geversink *et al.*, 1998).

Social stress in rats has a more long-term effect on body temperature than social stress in pigs. A single social defeat of 1 h in rats has an effect on the body temperature rhythm lasting for 4 days (Meerlo *et al.*, 1996). Although we did not observe a clear daily body temperature rhythm in the pigs in the present experiment, results indicate that a single social defeat in rats has more impact on the animal than a series of social conflicts after mixing of unacquainted pigs. However, rats were housed individually in an unfamiliar cage after the social defeat, whereas the pigs were housed in groups in their own pen with one familiar pen mate present. Being in a group with a familiar pen mate may have protected the pigs from negative effects of the social confrontations lasting for days. It has been shown in rats that the long-term effects of a single social defeat on behaviour and physiology are strongly reduced when the animals are housed in groups after the stress experience (Ruis *et al.*, 1999), suggesting that social support may play an important rôle in the protection of social animals from the negative consequences of stress. However, in situations of more unstable groups of pigs, in which the frequency of agonistic behaviour is increased for days after the time of mixing, mixing may have a more long-term effect on the body temperature. Results of this experiment indeed showed individual variation in the duration of the hyperthermia after mixing. In some pigs the hyperthermic response lasted only 3 to 4 h, whereas in other pigs the hyperthermic response lasted for more than 24 h (data not shown).

Ekkel (1996) measured peripheral temperature in transported and mixed pigs and observed that transported and mixed pigs had an increased peripheral temperature during 10 weeks after the stress experience as compared with unmixed control pigs. However, it is unclear to what extent peripheral body temperature reflects changes in deep body temperature (Ekkel, 1996). Since Ekkel (1996) only measured peripheral temperature in one mixed group it may also have been possible that body temperature was measured in a very unstable group

with frequently occurring agonistic interactions during the weeks after mixing.

Mixed pigs had a lower frequency of eating than control pigs. A decrease of food intake is a sign of sickness behaviour that is also observed during fever in pigs (Johnson and Von Borell, 1994). Although we did not measure food intake, results of the present experiment indicate that the decreased frequency of eating after mixing may be caused by feelings of sickness.

The general activity level did not differ significantly between mixed and control pigs. This indicates that the increased deep body temperature level in mixed pigs cannot be ascribed to an increased activity level only. Heetkamp *et al.* (1995) also showed that mixing has little effect on general activity. In that experiment activity-related heat production was only increased during the 1st h after mixing. However, in the present experiment an increased frequency of fighting was observed, which is a high energetic activity. The increased muscular activity due to fighting, together with injuries caused by fighting may have contributed to the hyperthermic response. Thus, results of the present experiment and of Heetkamp *et al.* (1995) indicate that psychological stress as well as physical activity and injury contribute to the hyperthermic response in the pigs after mixing.

We showed that no significant effects of mixing on heart rate were found. Acute and short-lasting changes in heart rate were observed in response to agonistic encounters (data not shown), indicating that the heart rate responses were largely influenced by physical activity as suggested earlier (Marchant *et al.*, 1995). Heart rate may therefore not be used as a sensitive parameter to measure long-term effects of stress.

In summary, the present experiment showed that mixing has a large effect on the deep body temperature in growing pigs. Deep body temperature is therefore a sensitive parameter to measure long-term effects of psychological stress in pigs.

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